RESEARCH ARTICLE OPEN ACCESS

Modeling Mass-Spring-Damper System using Simscape

Abhilash Ingale*, Anchal Daga*,Rajkumar Naik*
**(Final year B.Tech, Mechanical Engineering, Government College of Engineering, Amravati*
Corresponding Author: Abhilash Ingale,*

ABSTRACT
In this paper, the dynamic behavior of mass-spring-damper system has been studied by mathematical equations. Based on Newtonian mechanics, the mathematical model for a single mass-damper system is established. The transfer function of this model specifies the behavior of the component. The results of this analytical model are used as validation for the Simscape model**.**
Keywords: Damper, Non-linear mechanics, oscillatory motion, Simscape, Step size.

Date of Submission: 02-1-2018 Date of acceptance: 08-01-2018

I. INTRODUCTION

Simscape Multi-body, a simulation tool of MATLAB software, has been used to model and study the behavior of dynamic systems, using predefined blocks. It has provisions to interface with Simulink and therefore enables direct integration with mechanical and electronic systems, thereby representing an integrated coupled multi-physical domain [1]. In the present work, the physical model of the coupled spring-mass system with damper and 1 DOF is designed in Simscape Multi-body and validated with MATLAB.

The dynamic testing of the model using the spring stiffness and damping coefficient can be effectively performed in Simscape environment in Simulink. For this simulation, the geometry of a block is defined as shown in Fig.1.

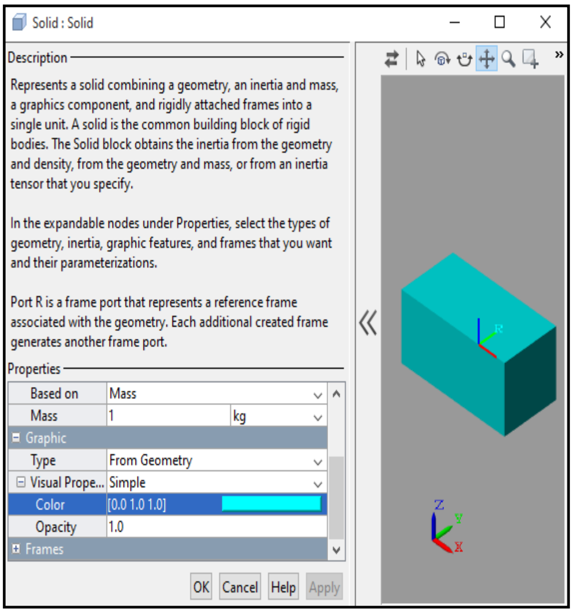

Fig. 1:- Geometry of the block

II. REPRESENTATION OF SYSTEM

The physical model of the spring-mass system with damper and its Simscape block representation has been shown in Fig.2[2]. The properties of the solid are specified in the solid block. Relative motion between the bodies may be specified by using joint block. In this model, the relative translational motion is defined by a prismatic joint (shown in Fig.2). The coefficient of stiffness and damping properties has been specified in the prismatic joint. The world frame block is the fixed frame of reference for the model in global coordinates. The solver configuration block gives access to special settings in Simscape environment which is very convenient for physical modeling.

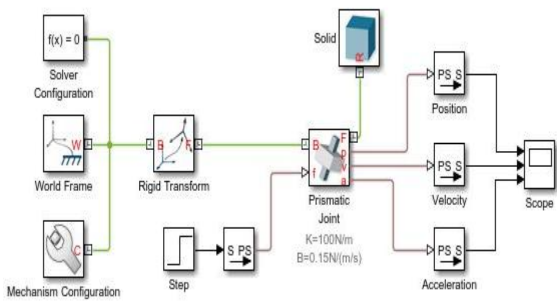

Fig. 2: - Simscape model of the single-mass system

I. MATHEMATICAL MODEL FORMULATION

The spring-mass responses, obtained from the Simscape model, have been validated with an equivalent mathematical model. The spring-mass has 1 translational degree of freedom.

Consider the mechanical system as shown in Fig.3. Due to the applied force F, the solid body will displace by an amount x in the direction of the applied force.

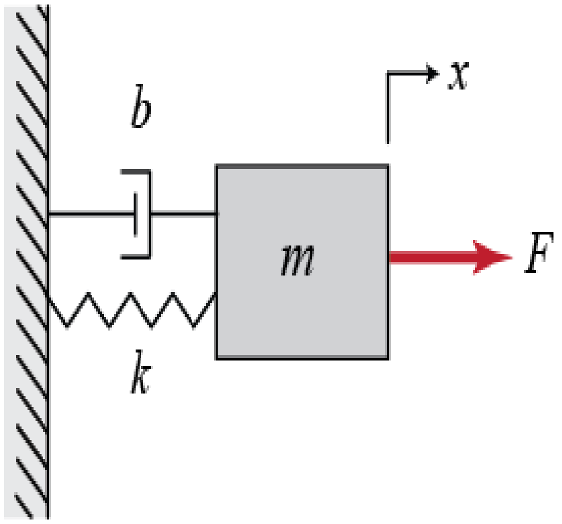

Fig.3 :- Mechanical system for single mass-spring and damper system

According, to Newton's Law of motion the applied force will cause displacement in spring, acceleration of the mass of body against the frictional force[3].

The generalized equation for the system can be formulated as follows,

$$F = m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx \quad \dots (1)$$

Where, F = Force
m= mass of system
b= Damping coefficient
k= spring coefficient
x= displacement

The above equation can be solved mathematically by using transfer function. The transfer function is the mathematical function giving the corresponding output value for each value possible value of the input to the system [4]. The results are represented as characteristic transfer curve.

In the given system, force (F) is the input to the system and displacement (x) is the output.
The Laplace form of the above equation is,

$$F(s) = [ms^2x(s) + Csx(s) + kx(s)] \quad \dots (2)$$

$$F(s) = [ms^2 + Cs + kx]x(s) \quad \dots (3)$$

$$\frac{x(s)}{F(s)} = \frac{1}{ms^2+Cs+k} \quad \dots (4)$$

This transfer function is solved in MATLAB.
The solution of above equation can be obtained by Rung-Kutta method as follows,

Equation (1) can be written as;

$$m\ddot{x} + C\dot{x} + kx = F \quad \dots (5)$$

Let $\dot{x} = v$ ... (6)

So the above equation (5) reduces to,

$$\dot{v} = \left[\left(\frac{F}{m}\right) - \left(\frac{C}{m}\right)v - \left(\frac{k}{m}\right)x\right] \quad \dots (7)$$

We can see that second order differential equation has been reduced to first order differential equations.
For our convenience, put

$x = y(1)$;

$\dot{x} = v = y(2)$;

Equation (6) and (7) then reduce to

$\dot{y}(1) = y(2)$;

$$\dot{y}(2) = \left[\left(\frac{F}{m}\right) - \left(\frac{C}{m}\right) * y(2) - \left(\frac{k}{m}\right) * y(1)\right] \dots (8)$$

MATLAB code of the above equation is written and a graph of displacement Vs time and velocity Vs time are drawn analytically as shown in Fig.4 and Fig. 5

The parameters used for solving this function and for simulation purpose are as follows:

Table 1: Parameters For Block

Parameter	Value
Mass of solid (m)	1.0 kg
Spring constant (k)	100 N/m
Damping coeff. (C)	0.15 N/(m/s)
Force applied (F)	100 N

II. RESULTS AND DISCUSSION

The position and velocity of the spring-damper system are generated by solving the developed transfer function using MATLAB. The displacement graph is shown in Fig 4 while the velocity graph is shown in Fig 5.

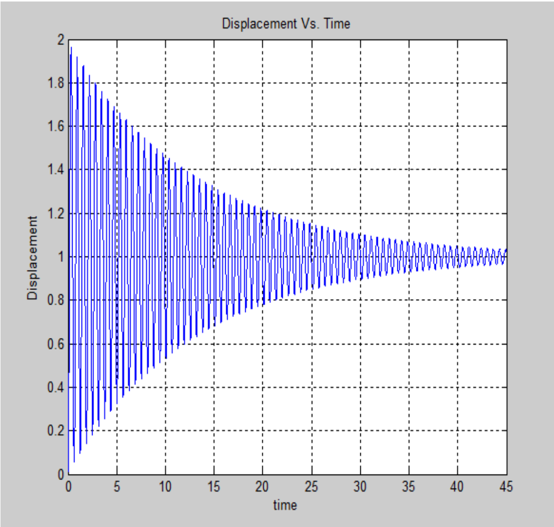

Fig 4:- Displacement vs Time

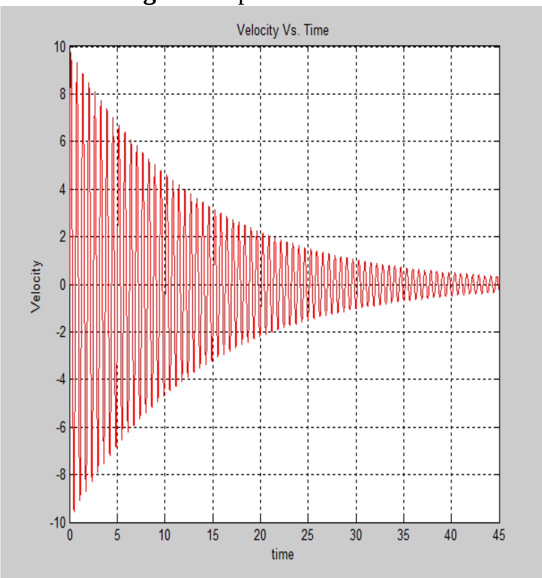

Fig 5:- Velocity vs Time

Similarly, the Simscape model results for position and velocity are shown in Fig 6. The result obtained using the analytical method from MATLAB and physical modeling in Simscape environment is compared.

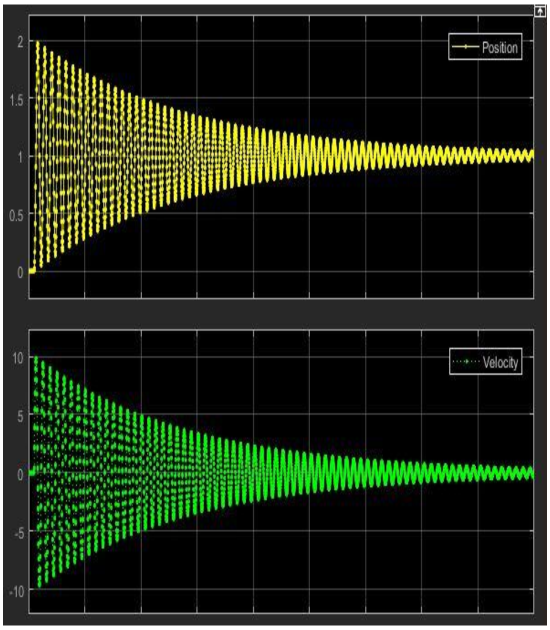

Fig.6:- Position and velocity plot for simscape

For the given parameters of the system, the position vs. time response in Simscape gives the maximum value of displacement equal to 1.973 m while the analytical model in MATLAB gives the maximum value equal to 1.961 m. Similarly, the maximum velocity as per Simscape model is found to be 9.875 m/s while according to the analytical method it is 9.761 m/s. The table below compares the results for maximum velocity and displacement.

TABLE 2:- Comparison of Simscape and analytical model

Parameter	Simscape	Analytical
Displacement	1.973 m	1.961 m
Velocity	9.875 m/s	9.761 m/s

The percentage change in maximum displacement is 0.6 % and that of maximum velocity is 1.17 % with respect to the analytical model.

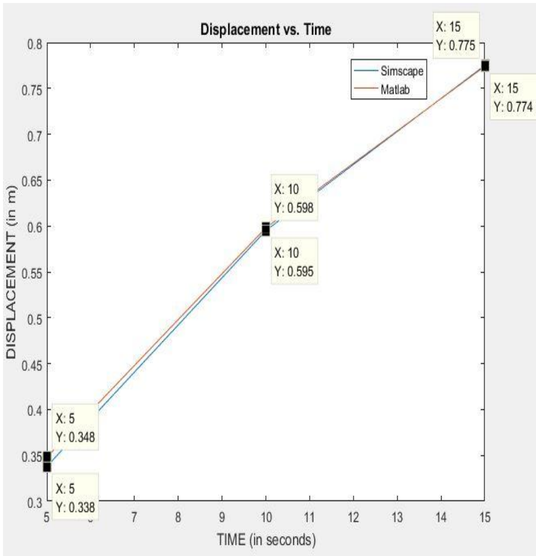

Fig 7:- Simscape and MATLAB results for displacement vs time

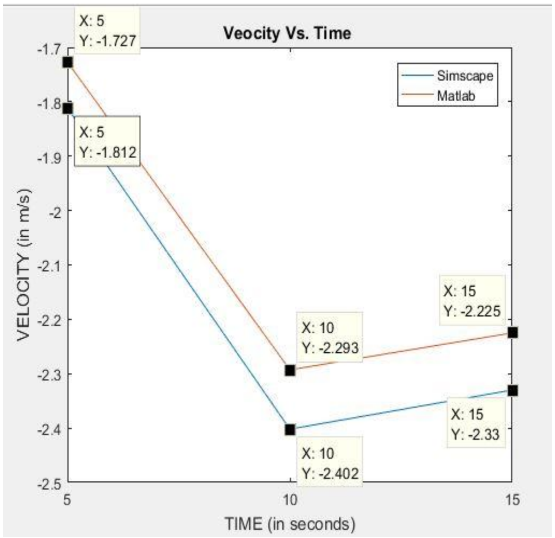

Fig. 8:- Comparison of simscape and MATLAB results for velocity vs time

The values from Simscape and MATLAB were plotted for various instants of time (t=5s, t=10s, t=15s) and the resultant deviation was observed from Fig 7 and Fig 8.

Thus, we see that the deviation of Simulink model from analytical solution increases with a higher order of differential. Simscape and analytical model both use the solver ode45 for solving the differential equation for the spring-mass-damper system. The observed difference is due to the automatic variable step size setting used in the Simscape environment.

IV. CONCLUSION

A single mass system, with one degree of freedom, has been developed in Simscape and validated successfully with an equivalent mathematical model, using transfer function in MATLAB. The developed Simscape model can be used further for dynamic and control related studies of spring mass damper systems. Thus, it is shown that behavior of physical multi-body systems can be effectively studied in Simscape environment without the need for developing complex mathematical equations.

REFERENCES

[1]. Venkatasubramanian, Saayan Banerjee, V.Balamurugan, 'Non-linear seventeen degrees of freedom ride dynamics model of a full-tracked vehicle in SimMechanics', 12th International Conference on Vibration Problems, ICOVP 2015.

[2]. Ashish Singla, Gurminder Singh, Gurvinder Singh Virk, 'Matlab/SimMechanics based control of four-bar passive lower-body mechanism for rehabilitation', Perspectives in Science (2016) 8, 351—354, Science direct journal

[3]. Dragan Sekulic, Vlastmir Dedovic, 'The Effect of Stiffness and damping of The Suspension System Element on The Optimization of Vibrational Behavior of a Bus', UDC; 629.341.027.421

[4]. https://en.wikipedia.org/wiki/Transfer_function

Abhilash Ingale*,"Modeling Mass-Spring-Damper System using Simscape." International Journal of Engineering Research and Applications (IJERA), vol. 08, no. 01, 2018, pp. 30–33.